What I claim is:

1. A method for providing ventilatory assistance to a spontaneously breathing patient comprising continuously repeating the steps of:

determining respiratory airflow,

computing a measure of the difference between a function of respiratory airflow over a period of time and a target value,

determining the phase of the current breathing cycle, and

delivering air to the patient at a pressure that is a function of the product of (a) said difference measure, (b) the amplitude at the determined phase of the current breathing cycle of an amplitude-versus-phase template that is appropriate for a normal breathing cycle, and (c) a gain factor that varies depending on the magnitude of said difference measure.

2. A method for providing ventilatory assistance in accordance with claim 1 wherein said gain factor increases with the magnitude of said difference measure.

3. A method for providing ventilatory assistance in accordance with claim 2 wherein for equal difference measures below and above said target value, the gain factor is greater for difference measures below said target value.

4. A method for providing ventilatory assistance in accordance with claim 3 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

5. A method for providing ventilatory assistance in accordance with claim 1 wherein the phase of the current breathing cycle is determined by relating respiratory airflow and its rate of change to different phases of a normal breathing cycle.

6. A method for providing ventilatory assistance in accordance with claim 5 wherein said relating step includes application of a set of fuzzy logic rules.

7. A method for providing ventilatory assistance in accordance with claim 1 wherein said difference measure is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said difference measure the pressure of the delivered air is changed in a respective direction that tends to reduce said difference

measure.

8. A method for providing ventilatory assistance in accordance with claim 1 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

9. A method for providing ventilatory assistance to a spontaneously breathing patient comprising continuously repeating the steps of:

determining respiratory airflow,

computing a measure of the difference between a function of respiratory airflow over a period of time and a target value, and

delivering air to the patient at a pressure that is a function of said difference measure by using a blower in a servo-controlled loop whose gain varies depending on the magnitude of said difference measure.

10. A method for providing ventilatory assistance in accordance with claim 9 wherein for respiratory airflows that are above said target value the gains are less than the gains for corresponding respiratory airflows that are below said target value.

11. A method for providing ventilatory assistance in accordance with claim 9 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

12. A method for providing ventilatory assistance in accordance with claim 9 wherein said difference measure is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said difference measure the pressure of the delivered air is changed in a respective direction that tends to reduce said difference measure.

13. A method for providing ventilatory assistance to a spontaneously breathing patient comprising the steps of:

determining respiratory airflow,

determining the difference between respiratory airflow over a period of time and a target value, and

using a blower in a servo-controlled loop that responds to said difference by delivering air to the patient, the servo-controlled loop having a gain that increases with the magnitude of said difference.

14. A method for providing ventilatory assistance in accordance with claim 13 wherein for respiratory airflows that are above said target value the gains are less than the gains for corresponding respiratory airflows that are below said target value.

15. A method for providing ventilatory assistance in accordance with claim 13 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

16. A method for providing ventilatory assistance in accordance with claim 13 wherein said difference is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said difference the pressure of the delivered air is changed in a respective direction that tends to reduce said difference.

17. A method for providing ventilatory assistance to a spontaneously breathing patient comprising continuously repeating the steps of:

determining respiratory airflow,

computing a measure of the difference between a function of respiratory airflow over a period of time and a target value that is an alveolar ventilation which takes into account the patient's physiologic dead space,

determining the phase of the current breathing cycle, and

delivering air to the patient at a pressure that is a function of the product of (a) said difference measure and (b) the amplitude at the determined phase of the current breathing cycle of an amplitude-versus-phase template that is appropriate for a normal breathing cycle.

18. A method for providing ventilatory assistance in accordance with claim 17 wherein air is delivered to said patient by using a blower in a servo-controlled loop that responds to said difference measure, the servo-controlled loop having a gain that increases with the magnitude of said difference measure.

19. A method for providing ventilatory assistance in accordance with claim 18

wherein for respiratory airflows that are above said target value the gains are less than the gains for corresponding respiratory airflows that are below said target value.

20. A method for providing ventilatory assistance in accordance with claim 17 wherein the phase of the current breathing cycle is determined by relating respiratory airflow and its rate of change to different phases of a normal breathing cycle.

21. A method for providing ventilatory assistance in accordance with claim 20 wherein said relating step includes application of a set of fuzzy logic rules.

22. A method for providing ventilatory assistance in accordance with claim 17 wherein said difference measure is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said difference measure the pressure of the delivered air is changed in a respective direction that tends to reduce said difference measure.

23. A method for providing ventilatory assistance to a spontaneously breathing patient comprising the steps of:

determining respiratory airflow,

computing a measure of the difference between a function of respiratory airflow over a period of time and a target value that is an alveolar ventilation which takes into account the patient's physiologic dead space, and

delivering air to the patient at a pressure that is a function of said difference measure by using a blower in a servo-controlled loop whose gain varies depending on the magnitude of said difference measure.

24. A method for providing ventilatory assistance in accordance with claim 23 wherein the servo-controlled loop has a gain that increases with the magnitude of said difference.

25. A method for providing ventilatory assistance in accordance with claim 24 wherein for respiratory airflows that are above said target value the gains are less than the gains for corresponding respiratory airflows that are below said target value.

26. A method for providing ventilatory assistance in accordance with claim 23 wherein said difference measure is a clipped integral of the respiratory airflow minus

said target value, and for either polarity of said difference measure the pressure of the delivered air is changed in a respective direction that tends to reduce said difference measure.

27. A method for providing ventilatory assistance to a spontaneously breathing patient comprising the steps of:

determining respiratory airflow,

integrating the difference between a function of the respiratory airflow and a target value to derive an error signal,

determining the phase of the current breathing cycle,

using the error signal to servo control the pressure of air delivered to the patient,

using an amplitude-versus-phase template that is appropriate for a normal breathing cycle, further controlling the pressure of air delivered to the patient in accordance with the template amplitude at the determined phase of the current breathing cycle, and

adjusting the gain of the servo control in accordance with the magnitude of said error signal.

28. A method for providing ventilatory assistance in accordance with claim 27 wherein said gain increases with the magnitude of said error signal.

29. A method for providing ventilatory assistance in accordance with claim 28 wherein for equal error signals below and above said target value, the gain is greater for error signals below said target value.

30. A method for providing ventilatory assistance in accordance with claim 29 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

31. A method for providing ventilatory assistance in accordance with claim 27 wherein the phase of the current breathing cycle is determined by relating respiratory airflow and its rate of change to different phases of a normal breathing cycle.

32. A method for providing ventilatory assistance in accordance with claim 31

wherein said relating step includes application of a set of fuzzy logic rules.

33. A method for providing ventilatory assistance in accordance with claim 27 wherein said error signal is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said error signal the pressure of the delivered air is changed in a respective direction that tends to reduce said error signal.

34. A method for providing ventilatory assistance in accordance with claim 27 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

35. A method for providing ventilatory assistance to a spontaneously breathing patient comprising the steps of:

determining respiratory airflow,

integrating the difference between a function of the respiratory airflow and a target value to derive an error signal,

using the error signal to servo control the pressure of air delivered to the patient, and

adjusting the gain of the servo control in accordance with the magnitude of said error signal.

36. A method for providing ventilatory assistance in accordance with claim 35 wherein said gain increases with the magnitude of said error signal.

37. A method for providing ventilatory assistance in accordance with claim 36 wherein for equal error signals below and above said target value, the gain is greater for error signals below said target value.

38. A method for providing ventilatory assistance in accordance with claim 37 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

39. A method for providing ventilatory assistance in accordance with claim 35 wherein said error signal is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said error signal the pressure of the delivered air is changed in a respective direction that tends to reduce said error signal.

40. A method for providing ventilatory assistance in accordance with claim 35 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

41. Apparatus for providing ventilatory assistance to a spontaneously breathing patient comprising:

processing means for computing a measure of the difference between a function of respiratory airflow over a period of time and a target value, and for determining the phase of the current breathing cycle, and

a control mechanism for causing a blower to deliver air to the patient at a pressure that is a function of said difference measure, the amplitude at the determined phase of the current breathing cycle of an amplitude-versus-phase template that is appropriate for a normal breathing cycle, and a gain factor that varies depending on the magnitude of said difference measure.

42. Apparatus for providing ventilatory assistance in accordance with claim 41 wherein said gain factor increases with the magnitude of said difference measure.

43. Apparatus for providing ventilatory assistance in accordance with claim 42 wherein for equal difference measures below and above said target value, the gain factor is greater for difference measures below said target value.

44. Apparatus for providing ventilatory assistance in accordance with claim 43 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

45. Apparatus for providing ventilatory assistance in accordance with claim 41 wherein said processing means determines the phase of the current breathing cycle by relating respiratory airflow and its rate of change to different phases of a normal breathing cycle.

46. Apparatus for providing ventilatory assistance in accordance with claim 45 wherein processing means utilizes a set of fuzzy logic rules.

47. Apparatus for providing ventilatory assistance in accordance with claim 41 wherein said difference measure is a clipped integral of the respiratory airflow minus

said target value, and for either polarity of said difference measure said control mechanism causes the pressure of the delivered air to be changed in a respective direction that tends to reduce said difference measure.

48. Apparatus for providing ventilatory assistance in accordance with claim 41 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

49. Apparatus for providing ventilatory assistance to a spontaneously breathing patient comprising:

processing means for computing a measure of the difference between a function of respiratory airflow over a period of time and a target value, and

a control mechanism for causing a blower to deliver air to the patient at a pressure that is a function of said difference measure, the control mechanism using a blower in a servo-controlled loop whose gain varies depending on the magnitude of said difference measure.

50. Apparatus for providing ventilatory assistance in accordance with claim 49 wherein for respiratory airflows that are above said target value the control mechanism uses gains that are less than the gains for corresponding respiratory airflows that are below said target value.

51. Apparatus for providing ventilatory assistance in accordance with claim 49 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

52. Apparatus for providing ventilatory assistance in accordance with claim 49 wherein said difference measure is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said difference measure said control mechanism causes the pressure of the delivered air to be changed in a respective direction that tends to reduce said difference measure.

53. Apparatus for providing ventilatory assistance to a spontaneously breathing patient comprising:

processing means for computing a measure of the difference between a function

of respiratory airflow over a period of time and a target value that is an alveolar ventilation which takes into account the patient's physiologic dead space, and for determining the phase of the current breathing cycle, and

a control mechanism for causing a blower to deliver air to the patient at a pressure that is a function of said difference measure, and the amplitude at the determined phase of the current breathing cycle of an amplitude-versus-phase template that is appropriate for a normal breathing cycle.

54. Apparatus for providing ventilatory assistance in accordance with claim 53 wherein said control mechanism causes air to be delivered to said patient by using a blower in a servo-controlled loop that responds to said difference measure, the servo-controlled loop having a gain that increases with the magnitude of said difference measure.

55. Apparatus for providing ventilatory assistance in accordance with claim 54 wherein for respiratory airflows that are above said target value said control mechanism uses loop gains that are less than the gains for corresponding respiratory airflows that are below said target value.

56. Apparatus for providing ventilatory assistance in accordance with claim 53 wherein said processing means determines the phase of the current breathing cycle by relating respiratory airflow and its rate of change to different phases of a normal breathing cycle.

57. A method for providing ventilatory assistance in accordance with claim 53 wherein said processing means applies a set of fuzzy logic rules.

58. Apparatus for providing ventilatory assistance in accordance with claim 53 wherein said difference measure is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said difference measure said blower delivers air at a pressure that is changed in a respective direction that tends to reduce said difference measure.

59. Apparatus for providing ventilatory assistance to a spontaneously breathing patient comprising:

processing means for computing a measure of the difference between a function

of respiratory airflow over a period of time and a target value that is an alveolar ventilation which takes into account the patient's physiologic dead space, and

a control mechanism for causing a blower to deliver air to the patient at a pressure that is a function of said difference measure.

60. Apparatus for providing ventilatory assistance in accordance with claim 59 wherein said control mechanism operates a servo-controlled loop whose gain increases with the magnitude of said difference measure.

61. Apparatus for providing ventilatory assistance in accordance with claim 60 wherein for respiratory airflows that are above said target value said control mechanism uses loop gains that are less than the gains for corresponding respiratory airflows that are below said target value.

62. Apparatus for providing ventilatory assistance in accordance with claim 59 wherein said difference measure is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said difference measure said blower delivers air at a pressure that is changed in a respective direction that tends to reduce said difference measure.

63. Apparatus for providing ventilatory assistance to a spontaneously breathing patient comprising:

processing means for deriving an error signal that is a measure of the difference between a function of respiratory airflow over a period of time and a target value, and for determining the phase of the current breathing cycle, and

a servo control mechanism for causing a blower to deliver air to the patient at a pressure that is a function of said error signal and the amplitude at the determined phase of the current breathing cycle of an amplitude-versus-phase template that is appropriate for a normal breathing cycle,

said servo control mechanism adjusting its gain in accordance with the magnitude of said error signal.

64. Apparatus for providing ventilatory assistance in accordance with claim 63 wherein said gain increases with the magnitude of said error signal.

65. Apparatus for providing ventilatory assistance in accordance with claim 64 wherein for equal error signals below and above said target value, said gain is greater for error signals below said target value.

66. Apparatus for providing ventilatory assistance in accordance with claim 65 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

67. Apparatus for providing ventilatory assistance in accordance with claim 63 wherein said processing means determines the phase of the current breathing cycle by relating respiratory airflow and its rate of change to different phases of a normal breathing cycle.

68. Apparatus for providing ventilatory assistance in accordance with claim 67 wherein said processing means applies a set of fuzzy logic rules.

69. Apparatus for providing ventilatory assistance in accordance with claim 63 wherein said error signal is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said difference measure the pressure of the delivered air is changed in a respective direction that tends to reduce said difference measure.

70. Apparatus for providing ventilatory assistance in accordance with claim 63 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

71. Apparatus for providing ventilatory assistance to a spontaneously breathing patient comprising:

means for integrating the difference between a function of the respiratory airflow and a target value to derive an error signal, and

servo means responsive to the error signal for controlling the pressure of air delivered to the patient,

said servo means adjusting its gain in accordance with the magnitude of said error signal.

72. Apparatus for providing ventilatory assistance in accordance with claim 71 wherein said servo means increases its gain with the magnitude of said error signal.

73. Apparatus for providing ventilatory assistance in accordance with claim 72 wherein for equal error signals below and above said target value, said servo means uses a gain that is greater for error signals below said target value than for error signals above said target value.

74. Apparatus for providing ventilatory assistance in accordance with claim 71 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

75. Apparatus for providing ventilatory assistance in accordance with claim 71 wherein said error signal is a clipped integral of the respiratory airflow minus said target value, and for either polarity of said error signal the pressure of the delivered air is changed in a respective direction that tends to reduce said error signal.

76. Apparatus for providing ventilatory assistance in accordance with claim 71 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

77. A method for providing ventilatory assistance to a spontaneously breathing patient comprising continuously repeating the steps of:

determining respiratory airflow,

computing a measure of the difference between a function of respiratory airflow over a period of time and a target value,

delivering air to the patient at a pressure that is a function of said difference measure by using a blower in a servo-controlled loop whose gain varies depending on the magnitude of said difference measure, and

varying the gain more aggressively for conditions of hypoventilation than for conditions of hyperventilation.

78. A method for providing ventilatory assistance in accordance with claim 77 wherein for respiratory airflows that are above said target value the gains are less than the gains for corresponding respiratory airflows that are below said target value.

79. A method for providing ventilatory assistance in accordance with claim 77 wherein said target value is an alveolar ventilation that takes into account the patient's

physiologic dead space.

80. A method for providing ventilatory assistance in accordance with claim 77 wherein said difference measure is a function of relative ventilation error that is proportional to the difference between actual and target ventilations divided by target ventilation.

81. A method for providing ventilatory assistance in accordance with claim 77 wherein said pressure is flow-triggered and phase cycled.

82. A method for providing ventilatory assistance to a spontaneously breathing patient comprising continuously repeating the steps of:

determining respiratory airflow,

computing a measure of the difference between a function of respiratory airflow over a period of time and a target value,

delivering air to the patient at a pressure that is a function of said difference measure by using a blower in a servo-controlled loop whose gain varies depending on the magnitude of said difference measure, and

varying the gain to allow ventilation support to withdraw more gradually when the patient is over-ventilated than when the patient is under-ventilated.

83. A method for providing ventilatory assistance in accordance with claim 82 wherein for respiratory airflows that are above said target value the gains are less than the gains for corresponding respiratory airflows that are below said target value.

84. A method for providing ventilatory assistance in accordance with claim 82 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

85. A method for providing ventilatory assistance in accordance with claim 82 wherein said pressure is flow-triggered and phase cycled.

86. A method for providing ventilatory assistance to a spontaneously breathing patient comprising the steps of:

determining two patient ventilation measures with different speeds of response,

one fast and one slow,

deriving two error signals that are functions of a target value and respective ones of the two patient ventilation measures,

deriving two control responses corresponding to the two error signals,

adjusting each control response in accordance with the amplitude and sign of a corresponding one of said error signals such that the control response to error in the fast ventilation measure is more vigorous than the control response to error in the slow ventilation measure,

combining both control responses to produce an overall control response in such a way as to increasingly favor the control response to the fast ventilation measure over the control response to the slow ventilation measure as the fast response ventilation measure becomes increasingly less than the target value, and

using the overall control response to control the pressure of air delivered to the patient.

87. A method for providing ventilatory assistance in accordance with claim 86 wherein the degree of control increases with the magnitudes of said error signals.

88. A method for providing ventilatory assistance in accordance with claim 87 wherein for equal error signals below and above said target value, the degree of control is greater for error signals below said target value.

89. A method for providing ventilatory assistance in accordance with claim 86 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

90. Apparatus for providing ventilatory assistance to a spontaneously breathing patient comprising a control mechanism for determining respiratory airflow and computing a measure of the difference between a function of respiratory airflow over a period of time and a target value; and a servo-controlled blower for delivering air to the patient at a pressure that is a function of said difference measure, the pressure depending on the magnitude of said difference measure; the blower changing the pressure more aggressively for conditions of hypoventilation than for conditions of

hyperventilation.

91. Apparatus for providing ventilatory assistance in accordance with claim 90 wherein for respiratory airflows that are above said target value the pressure is changed less aggressively than it is changed for corresponding respiratory airflows that are below said target value.

92. Apparatus for providing ventilatory assistance in accordance with claim 90 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

93. Apparatus for providing ventilatory assistance in accordance with claim 90 wherein said difference measure is a function of relative ventilation error that is proportional to the difference between actual and target ventilations divided by target ventilation.

94. Apparatus for providing ventilatory assistance in accordance with claim 90 wherein said pressure is flow-triggered and phase cycled.

95. Apparatus for providing ventilatory assistance to a spontaneously breathing patient comprising a control mechanism for determining respiratory airflow and computing a measure of the difference between a function of respiratory airflow over a period of time and a target value; and a servo-controlled blower for delivering air to the patient at a pressure that is a function of said difference measure, the pressure depending on the magnitude of said difference measure; the blower allowing ventilation support to withdraw more gradually when the patient is over-ventilated than when the patient is under-ventilated.

96. Apparatus for providing ventilatory assistance in accordance with claim 95 wherein for respiratory airflows that are above said target value the blower effects pressure changes more slowly than it does for corresponding respiratory airflows that are below said target value.

97. Apparatus for providing ventilatory assistance in accordance with claim 95 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

98. Apparatus for providing ventilatory assistance to a spontaneously breathing

patient comprising a control mechanism for determining two patient ventilation measures with different speeds of response, one fast and one slow, for deriving two error signals that are functions of a target value and respective ones of the two patient ventilation measures, for deriving two control responses corresponding to the two error signals, for adjusting each control response in accordance with the amplitude and sign of a corresponding one of said error signals such that the control response to error in the fast ventilation measure is more vigorous than the control response to error in the slow ventilation measure, and for combining both control responses to produce an overall control response in such a way as to increasingly favor the control response to the fast ventilation measure over the control response to the slow ventilation measure as the fast response ventilation measure becomes increasingly less than the target value; and a blower responsive the overall control response for controlling the pressure of air delivered to the patient.

99. Apparatus for providing ventilatory assistance in accordance with claim 98 wherein the degree of control exercised by said blower increases with the magnitudes of said error signals.

100. Apparatus for providing ventilatory assistance in accordance with claim 98 wherein for equal error signals below and above said target value, the degree of control exercised by said blower is greater for error signals below said target value.

101. Apparatus for providing ventilatory assistance in accordance with claim 98 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

102. A method for providing ventilatory assistance to a spontaneously breathing patient comprising continuously repeating the steps of:

determining the patient's ventilation,

from the determined ventilation calculating either an absolute or relative ventilation error compared to a target value,

deriving a pressure support amplitude that is a function of the product of the ventilation error and a gain that increases with ventilation error, and

delivering air to the patient at a pressure that is a function of said pressure

support amplitude.

103. A method for providing ventilatory assistance in accordance with claim 102 wherein for patient ventilations that are above said target value the gains are less than the gains for corresponding patient ventilations that are below said target value.

104. A method for providing ventilatory assistance in accordance with claim 102 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

105. A method for providing ventilatory assistance in accordance with claim 102 wherein the rate at which said pressure support amplitude changes is a function of both the magnitude and sign of the ventilation error.

106. A method for providing ventilatory assistance in accordance with claim 102 wherein the rate at which said pressure support amplitude changes is controlled to be faster for ventilation errors below said target value than for ventilation errors above said target value.

107. Apparatus for providing ventilatory assistance to a spontaneously breathing patient comprising a controller for determining the patient's ventilation, for calculating therefrom either an absolute or relative ventilation error compared to a target value, and for deriving a pressure support amplitude that is a function of the product of the ventilation error and a gain that increases with ventilation error; and a blower for delivering air to the patient at a pressure that is a function of said pressure support amplitude.

108. Apparatus for providing ventilatory assistance in accordance with claim 107 wherein for patient ventilations that are above said target value the gains are less than the gains for corresponding patient ventilations that are below said target value.

109. Apparatus for providing ventilatory assistance in accordance with claim 107 wherein said target value is an alveolar ventilation that takes into account the patient's physiologic dead space.

110. Apparatus for providing ventilatory assistance in accordance with claim 107 wherein the rate at which said pressure support amplitude changes is a function of both the magnitude and sign of the ventilation error.

111. Apparatus for providing ventilatory assistance in accordance with claim 107 wherein the rate at which said pressure support amplitude changes is controlled to be faster for ventilation errors below said target value than for ventilation errors above said target value.

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